# Embodying climate change: How to cope with public confusion on global warming

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Abstract: The scientific consensus on the causes of climate change is in contrast to a widespread confusion among the public: Several studies indicate that not only school students and laypeople but even qualified science graduates face serious problems to explain how the emission and capture of CO2 influence the atmospheric CO2-budget and thus global warming. We use the theoretical framework of embodied cognition to analyse why the principles of climate change are so hard to grasp. Embodied cognition states that all of our conceptions base on physical and cultural experience. This experience is used either directly or metaphorically in understanding a phenomenon. Our analyses show that the atmospheric CO2- budget is interpreted with image schemata like containers, flows and balances. Each of these single schemata are embodied and shaped in early childhood. But to understand climate change these schemata are combined to a stock-and flow schema which is complex and unintuitive. Based on our findings we developed external representations of the atmospheric CO2-budget that address the students' confusion by two strategies: Whether we afforded an experience or we assisted the reflection on the stock- and flow schema by representing its image-schematic structure. We probed these external representations in teaching experiments with high-school and university students and discuss how embodied cognition can inform the development of external representations on stock- and flow relationships



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## Abstract

The scientific consensus on the causes of climate change is in contrast to a widespread confusion among the public: Several studies indicate that not only school students and laypeople but even qualified science graduates face serious problems to explain how the emission and capture of $CO_2$ influence the atmospheric $CO_2$-budget and thus global warming.

We use the theoretical framework of embodied cognition to analyse why the principles of climate change are so hard to grasp. Embodied cognition states that all of our conceptions base on physical and cultural experience. This experience is used either directly or metaphorically in understanding a phenomenon. Our analyses show that the atmospheric $CO_2$-budget is interpreted with image schemata like containers, flows and balances. Each of these single schemata are embodied and shaped in early childhood. But to understand climate change these schemata are combined to a stock-and flow schema which is complex and unintuitive.

Based on our findings we developed external representations of the atmospheric $CO_2$-budget that address the students' confusion by two strategies: Whether we afforded an experience or we assisted the reflection on the stock- and flow schema by representing its image-schematic structure. We probed these external representations in teaching experiments with high-school and university students and discuss how embodied cognition can inform the development of external representations on stock- and flow relationships.

**Extended Summary**

The scientific consensus on the causes of climate change is in contrast to a widespread confusion among the public. Several studies (e.g. Sterman et al. 2000; Author, 2012, 2013, 2014) indicate that not only school students but even qualified science graduates face serious problems to explain how the emission and capture of $CO_2$ influence the atmospheric $CO_2$-budget: Asked to predict the rate of $CO_2$-emissions and removal that is needed to stabilise the atmospheric $CO_2$-level, most students believe that stopping the growth of emissions stops the increase of $CO_2$ concentration (Sterman et al., 2000). That vast majority of students (84%) asserted that the atmospheric $CO_2$-level would stabilise even though emissions exceed removal. This is in fact wrong—emissions and removal need to be the same to stabilise the $CO_2$-level. We use the theoretical framework of embodied cognition to analyse why these principles of climate change are so hard to grasp.

**Theoretical Framework**

Conceptual metaphor as a theory within the framework of embodied cognition argues that understanding is ultimately grounded in embodied conceptions, either directly, or by imaginatively mapping its structure to the abstract concept to be understood. (Lakoff, 1990; Author, 2013). Embodied cognition explains why we have problems in understanding science concepts like climate change or the atmospheric $CO_2$-budget: They are of abstract nature and therefore imaginative thought is needed. The purpose of this study is to find out: *Which embodied conceptions guide students understanding of the $CO_2$-budget? How can external representations that address these embodied conceptions engender understanding the $CO_2$-budget?*

**Methods**

We collected students' and scientists' conceptions on the atmospheric $CO_2$ budget from an own interview study (Author 2010), from climate change reports (IPCC, 2013) and from a reanalysis of the study of Sterman et al. (2000). To analyse the conceptions, all data were investigated using qualitative content analysis (Mayring, 2002) and metaphor analysis (Schmitt, 2005). The data are presented on the level of conceptual metaphors (CM) (Lakoff, 1990). Based on the differences and commonalities between scientists' and students' conceptions we developed external representations (ER) that meet the students' learning demand. These external representations were probed in teaching experiments (Steffe, Thompson, & Glasersfeld, 2000) with 39 students in groups of 2-3 students.

**Results**

In our interview study we found that if even on a content level the conceptions of students differ widely from those of scientists, both draw the image schemata of containers and balances which can be analysed from the CMs they used (see table 1).

**Table 1**

| Students' Conceptual Metaphors | Scientists' Conceptual Metaphors |
|---|---|
| Constant $CO_2$-level By Constant Input | Constant $CO_2$-level By Balanced Input and Output |
| Constant $CO_2$-level By Less Input than Output | |

With these CMs in mind we developed ERs to visualise the dynamic aspects of equilibrium to foster students' understanding of the relation between the $CO_2$-emission/removal and the atmospheric $CO_2$-level. Before working with the ERs the students were asked to outline their

conception in a graph: "How do the $CO_2$-emissions and removals have to develop to keep a constant level of $CO_2$ in the atmosphere (i.e. limit global warming to 2 °C)?" This was the same task given by Sterman et al. (2000).
The results are presented by way of example and show (see Figure 1a) that initially the student Lena had the same difficulties as reported by Sterman et al. (2000): The emissions were stabilized but exceeded the removal.
From the perspective of the balance image schema this conception is based on the idea *Constant $CO_2$-level Is Constant Input*. In our teaching experiments we disclosed the balance schema in an ER consisting of a beaker with a valve at the bottom, fed and drained by water. If the valve at the bottom was medium open, the inflow and outflow of water were constant. Lena was asked to compare the amount of water in the beaker with the amount of $CO_2$ in the atmosphere:

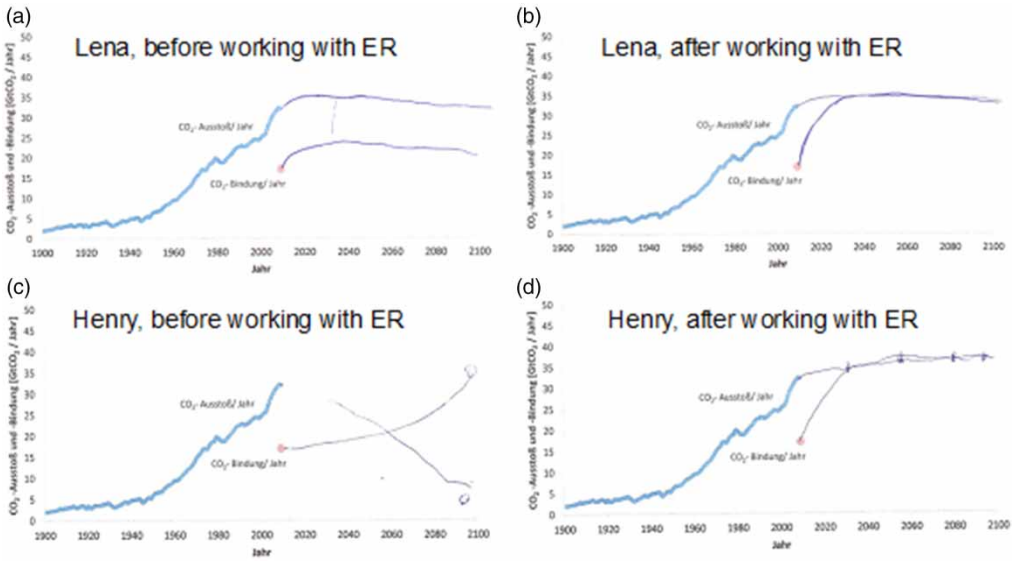
Lena: "In global warming more water flows into the beaker than leaving it."

Interviewer: "Can you please map your findings to the atmosphere?"

Lena: "To keep the temperature at a certain level, the input and output of water must be the same. Then the same amount of $CO_2$ must go into the atmosphere and leave it again."

In working with the ER of the atmospheric $CO_2$-level Lena starts by implicitly switching between arguing on the perceptible level of the beaker and the imperceptible level of the atmosphere. She refers to the balance image schema to construct a conception to explain global warming: *Warming Is More Inflow.* This conception brings together the water flow and global warming. She uses a related CM to construct an idea of how to keep the atmospheric temperature constant: *Stopping Warming Is Balancing Flows.* Here again she refers to the perceptibel water flow as a source for understanding. Finally, this understanding is mapped by her to the atmosphere when she exchanges the source domain water-flow to $CO_2$-flow (*Stopping Warming Is Balancing $CO_2$-Flows*). From the perspective of the balance schema she argues now with the CM *Constant $CO_2$-level Is Balancing Input and Output*.
After working with the ER, we asked Lena if she wants to redraw her initial diagram. The results presented in Figure 1b show that she is able to transfer the conceptual development initiated in working with the ER to draw a revised, and correct diagram.
After experiencing the balance schema and reflecting upon its adaption to the $CO_2$-budget 32 of 39 students were able to argue correctly.

**Figure 1**



## Discussion

Our analyses of students and scientists CMs on the $CO_2$-budget has shown that in this case students refer to the same image schemata as scientists. Divergences in the conceptions are due to a difference in mapping this image schematic structure to the $CO_2$-budget. Our ERs and reflecting on water flowing through a beaker are material representations of image schemata that students and scientists employ in understanding the carbon cycle. These ERs of cognitive schemata helped our students to re-experience the inherent structure of the schema, identify its essential elements, and reflect on how they employ it in their effort to understand the phenomenon. This kind of representation sheds light on the embodied conceptions that shape students' conceptual understanding. Models in classrooms often work in such a way that they provide new experiences students may use as a source for understanding. Representations that visualise an image schema and its mapping on a scientific concept work differently. They do not provide *new* experience; they induce an instance of a *relived* embodied experience. By working with these ER students got the chance to analyse the structure of this specific experience and reflect on their embodied cognition.

## Literature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